XVIII. Bioscience

SPACE SCIENCES DIVISION

N67-29159

A. Soil Studies — Desert Microflora. XIV. Soil Properties and Abundance of Microflora From a Soil Profile in McKelvey Valley, Antarctica,[1]

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1. Introduction

The Antarctic polar region is one of the coldest high-altitude deserts on Earth. Studies of the soil microflora of this region are of interest in connection with the detection and characterization of possible extraterrestrial microorganisms. They are also relevant to the Mars quarantine problem. Climate, which is one of the important factors for the development of soils and their microflora, is more rigorous and severe in Antarctica than in any other land area on this planet (Ref. 1). Organisms are either scarce, absent, or present only at certain seasons.

Antarctica is characterized by a dry atmosphere; the lowest mean temperatures on Earth; strong, persistent, cold, dry winds; and five months of continual darkness. Except in coastal areas, nearly all of the Antarctic mainland is covered by an ice sheet of 11.5×10^6 km^2, with a mean thickness of 2000 to 2500 m (Ref. 2). Precipitation (such as snow) is generally very low, and the relative humidity is also low, about one-tenth that of middle-latitude regions. The air contains relatively little dust or pollutants.

Other factors that can be of biological significance include the surface ozone concentration and soil surface temperatures. Surface ozone values, about 45 μg/m^3 of air, are about 25% higher than in middle latitudes of the Northern Hemisphere (Ref. 2). Relatively warm soil conditions can exist in the summer along the coast, and there is a significant difference in the radiation balance of rock and soil surface (Refs. 2–5).

Antarctic soils are primarily and typically desertic and immature, with very little distinctive morphogenesis or distinct horizons. Therefore they do not have a true profile. They are generally sandy, salty, very low in organic matter, and underlaid by permafrost (Ref. 4). Desert pavement of gravel, pebbles, cobbles and boulders, and frost-crack polygons are common surface features.

[1]Logistic support and facilities for this study in Antarctica were supplied by the National Science Foundation. H. P. Conrow and G. B. Blank of JPL Section 328 provided assistance in collection of samples and in measuring *in situ* properties.

Fig. 1. Location of soil site in McKelvey Valley, within Victoria Valley–Wright Valley complex, Victoria Land, Antarctica

The biotic factor has a negligible influence on exposed Antarctic land surfaces (Refs. 3–6). Plants are generally found only in some favorable habitats such as shallow ponds, around the faces of glaciers, in glacial outflow, and on some soil and rock surfaces. An investigation of these habitats shows that relatively warm, sheltered, moist microclimates or microenvironments at the air–surface interface are important for maintaining life. Primary factors for the survival and reproduction of organisms in the Antarctic environment include the ability to resist long periods of extreme desiccation, cold, and lack of solar energy. Masses of dead algae (without a single living alga) can be found around ponds, which attest to periods when survival was not possible in the rigorous Antarctic environment.

Lichens, algae, mosses, and fungi (the cryptogamic plants) are the primary life in Antarctica (Refs. 3, 5, and 6). Lichens and algae are the most abundant. The lichens appear to have morphological and physiological adaptations that enable them to best withstand the cold, desiccation, and winter dark period (Ref. 7). Algae and lichens are also the most abundant cryptogams in other desert areas (Ref. 8).

A review of microbiology of Antarctica (Ref. 9) indicates that a variety of microorganisms have been recovered from some habitats such as air, snow, ice, ponds, sea water, marine sediments, and Antarctic sea animals who spend part of their lives on the land or ice mass (Ref. 9). All of the different habitats, including the gastrointestinal microflora of warm-blooded animals (Ref. 9), showed a very low bacterial content. The cryptogamic flora provided a favorable habitat for microorganisms, but most soil samples contained relatively low abundances of populations (Ref. 9). In some soils there is a significant abundance of bacteria and fungi (molds); for other soils no or very little growth could be obtained using culture media for a wide variety of physiological groups (Ref. 10).

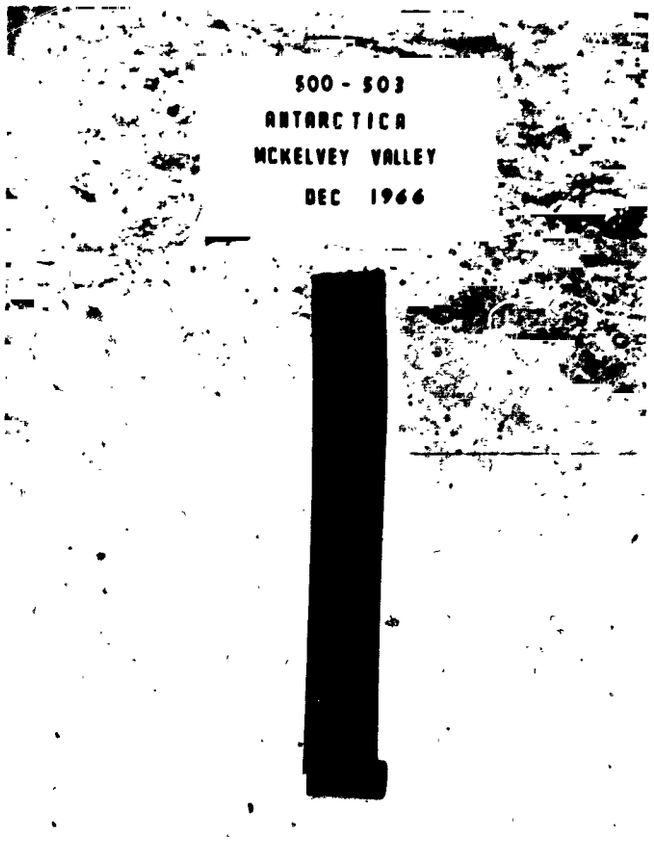
The study of Antarctic soils and microorganisms is a continuation of desert soil microbial ecology relative to possible extraterrestrial life in Martian soil. For this study, 26 soil sites and 76 samples were selected along the coast, primarily in "dry valley" areas of southern Victoria Land (Fig. 1). Two camps were established during the Antarctic austral summer, 1966–67. This report presents some of the results on soil properties and microflora determinations from one soil site at the McKelvey Valley camp, which existed from November 28 to December 11, 1966 (Fig. 2).

Fig. 2. Soil site and environmental instruments in McKelvey Valley (2730-ft elevation) with Olympus range in background. Approximately 80 mi from McMurdo Sound Station, Antarctica

2. Materials and Methods

By means of an aseptic technique previously developed for collecting and examining desert soils (Ref. 11), samples were taken from the surface 2-in. (No. 500),2- to 6-in. level (No. 501), 1-ft level (No. 502), and the lowest depth at 1.5 ft (No. 503) (Fig. 3). Care was taken to sterilize the collecting instruments (Fig. 4) before and after each sample was obtained from the pit (Fig. 5). All samples were placed in previously sterilized plastic-lined canvas sacks. Additional samples were taken for soil moisture, porosity, and bulk density, as described previously (Ref. 11). Soil temperature and relative humidity values were recorded to a depth of 1 ft. A few bacteriological fallout culture plates (trypticase soy agar and Sabouraud dextrose agar) were exposed at the soil surface for 2 hr (Fig. 6). Small amounts of fresh soil from each depth were also sprinkled over the surface of other culture plates (Fig. 7). All of these culture plates were incubated in the field and later examined at McMurdo Station.

For most purposes, samples were homogenized by passing them through a 2-mm sieve (No. 10 mesh). An aliquote of the sieved sample was powdered by mortar and pestle for appropriate physical and chemical analyses at JPL.



Official U.S. Navy photograph by C. L. Abramson, USN.

Fig. 3. Gravelly frozen soil in pit excavated in McKelvey Valley

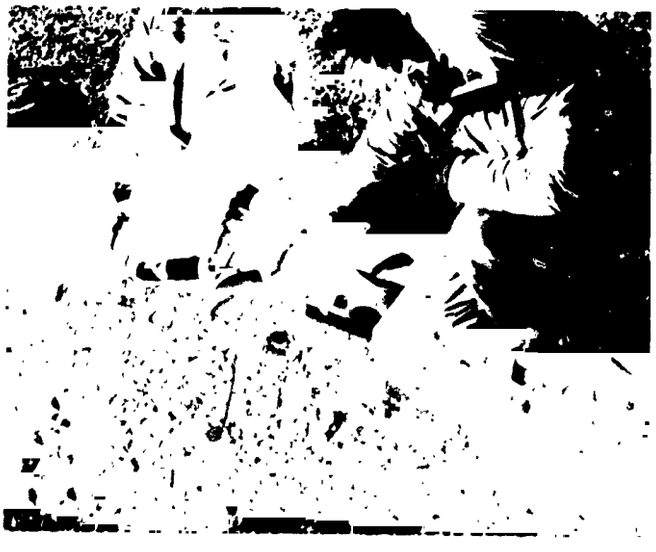


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Fig. 4. Sterilization of sample-collecting tool with propane torch prior to collection of soil samples

Official U.S. Navy photograph by C. L. Abramson, USN.

Fig. 5. Collecting soil sample from side of pit

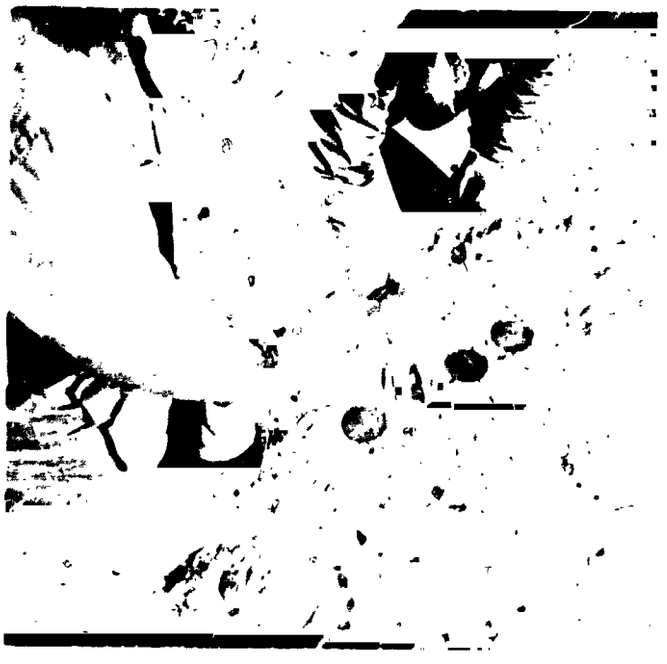

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Fig. 6. Placing microbiological fallout plates on soil surface near site

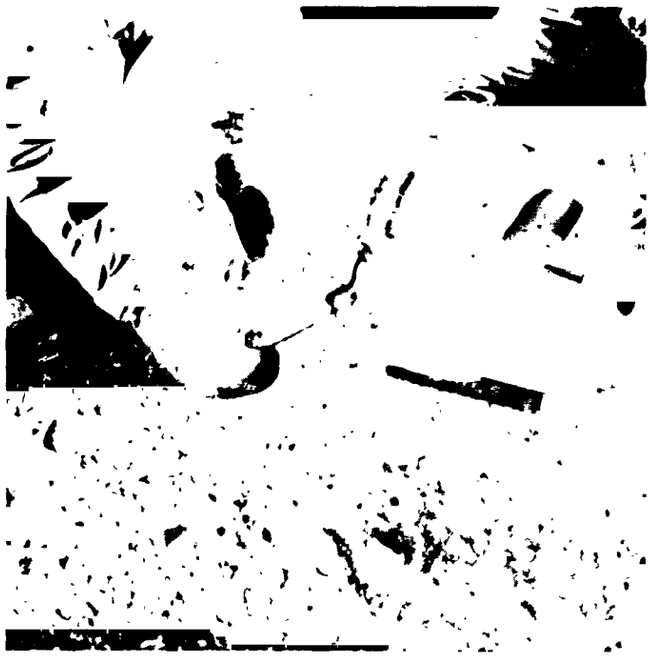

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Fig. 7. Sprinkling freshly procured surface soil on agar plates at soil site to determine presence of bacteria and fungi

a. Physical analyses. Soil color and Munsell notation were determined on both *in situ* (wet) and sieved (dry) soils by reference to Munsell Soil Color Charts. Textural class was estimated in the field by the standard method of feeling the soil. *In situ* moisture was determined gravimetrically by infrared drying to constant weight at 105°C. Bulk density and porosity, except for hard permafrost, were calculated from samples collected in standard soil-moisture tins.

b. Physicochemical analyses. Soil pH, Eh, and electrical conductivity were determined on the saturated soil paste (Ref. 12). Combustible materials were determined[2] by igniting the dry soil in air at 750°C for 30 min. The cation exchange capacity values were obtained by the modified barium chloride-triethanolamine procedure for calcareous soils (Ref. 13).[2] Mineralogical analyses[3] were obtained by X-ray diffraction with a scan speed of 0.5 deg/min.

c. Chemical analyses. Total carbon, hydrogen, and nitrogen analyses were performed by ignition in Coleman C-H and N-analyzers, as described previously (Ref. 14).[4] Organic C and carbonate C were obtained by the Allison method, utilizing acid digestion and gravimetric measurement of released CO_2 (Ref. 12).[4] The Kjeldahl method was used to obtain organic N (Ref. 12).[4] Total organic matter was estimated by using the factor 1.724 × wt % organic C. Sulfur and P were determined on $HClO_4$ extracts. Sulfur was determined by Na_2CO_3 fusion and P by the Truog–Meyer method (Ref. 13).[4] Standard colorimetric procedures or flame photometric detection were used to determine the presence or absence of available ions on 1:5, soil:water extracts. These ions included NH_4^+, NO_2^-, NO_3^-, Cl^-, Mn^{++}, SO_4^-, K^+, Na^+, Mg^{++}, Ca^{++}, and PO_4^-.[4] Spectrographic analyses were performed for all the other reported total elements by igniting soil (≲400 mesh) mixed with graphite using a dc arc.[5]

d. Microbiological analyses. Ten-gram quantities of sieved soil samples containing *in situ* moisture were suspended and dispersed by a reciprocating shaker for 20 min in deionized water. Deionized water was obtained by filtering distilled water through a Barnstead demineralizer. Following dispersion of the sample, the suspension was diluted serially by a 1:10 ratio and appropriate 1-cc aliquotes were pipetted into dilution tubes of selective media or disposable plastic petri dishes for pour plates.

For the various groups of microflora, this included the following media. (1) aerobic bacteria, trypticase soy agar; (2) microaerophilic bacteria, fluid thioglycollate medium; (3) anaerobes, trypticase soy agar in a reduced atmosphere obtained by mixing pyrogallic acid with concentrated NaOH; (4) actinomycetes, actinomycete agar; (5) sulfate reducers, Van Delden's sulfate reduction agar (Ref. 15); (6) fungi, Rose Bengal agar without antibiotics and Sabouraud dextrose agar; and (7) algae, Thornton's medium without organics (Ref. 15). Most of the media were prepared according to standard procedures, and can be recommended for various chemoautotrophic, heterotrophic, aerobic, anaerobic, and microaerophilic bacteria, actinomycetes, fungi, and algae. All incubations were carried out at variable room temperatures, at + 55 or + 4°C. All cultures were incubated at the NSF Biology Laboratory, McMurdo Sound Station, Antarctica, between December 19, 1966 and January 31, 1967.

[2] Analyses by L. Taylor, JPL Bioscience Section (326).

[3] Analyses by Dr. E. Bollin, JPL Bioscience Section (326).

[4] Analyses by Elek Microanalytical Laboratories, Torrance, California.

[5] Analyses by Pacific Spectro Chemical Laboratory, Los Angeles, California.

3. Results and Discussion

a. Contamination. McKelvey Valley presented a unique opportunity to investigate a cold, barren, windswept, glacier-cut area which had not been previously studied by soil scientists or microbiologists. In terms of geological time, this valley was relatively recently glaciated. It shows evidence of a third glaciation and may have been free of ice for approximately 10,000 years, although it is not yet possible to accurately date the stages of glacial recession in this area (Ref. 16).

Although McKelvey Valley was traversed in several directions for this study, at no time was there any evidence of previous human contamination; e.g., footprints, remains of camps, or refuse. However, on one day for about 15 min, a skua (gull-like sea bird) circled over the camp (Fig. 8) and rested for a few minutes about ⅛ mi from the soil site. On another occasion, while on traverse from another site, a desiccated piece of seal skin was found approximately 1 mi northeast of camp (Fig. 9).

Fig. 8. Skua circling over McKelvey site—possible source of contamination

Fig. 9. Desiccated piece of seal skin found about 1 mi northeast of camp (length of skin = ca. 4 in.)

There was no other evidence of seals, although desiccated and mummified seals were observed in other valleys (e.g.; Taylor Valley).

Before leaving the McKelvey camp, no discernible growth was noted on either the bacteriological fallout plates (Fig. 6) or the plates sprinkled with soil from the collection site (Fig. 7). Incubation period was from December 4 to 11, 1966 at variable temperatures, from below freezing to + 11°C. There was growth on some of the agar plates after arrival back at McMurdo, where incubation was continued at higher room temperatures, + 15 to + 23°C. Some of the control plates were contaminated, which made interpretation difficult, but a comparison with cultures made from processed McKelvey Valley soil at McMurdo showed that most of the microorganisms were similar. At nearly all times the wind was blowing in the valley, usually 5 to 15 mph, primarily from the northeast off the sea. There was undoubtedly a continual influx, although not necessarily an abundance, of airborne contaminants into the valley. The wind also scoured the valley floor, resulting in a desert pavement (Figs. 10 and 11); when walked upon or otherwise mechanically disturbed, fine particles of soil blew into the air and across the soil surface, serving as contamination for other windswept areas. Helicopter landings near the camp were an additional source responsible for spreading airborne contaminants or fine soil particles. Thirty- to forty-mph winds were created by the wash of helicopters, as recorded by the wind system at the camp site.

Fig. 10. Rocky, gravelly, and bouldery desert pavement at soil site

b. Soil analyses. A summary of the characteristics of the four soils is given in Tables 1–6. Physical determinations (Table 1) showed a narrow range of greyish, yellowish, or brownish sandy soils, which were composed primarily of quartz, and secondarily of oligoclase. Both of these minerals are common in rock formations and soils. With depth of soil, the amount of coarse materials $\leqq 2$ mm was found to increase. There was a slight increase of moisture with depth of soil, and subsurface soils appeared and felt

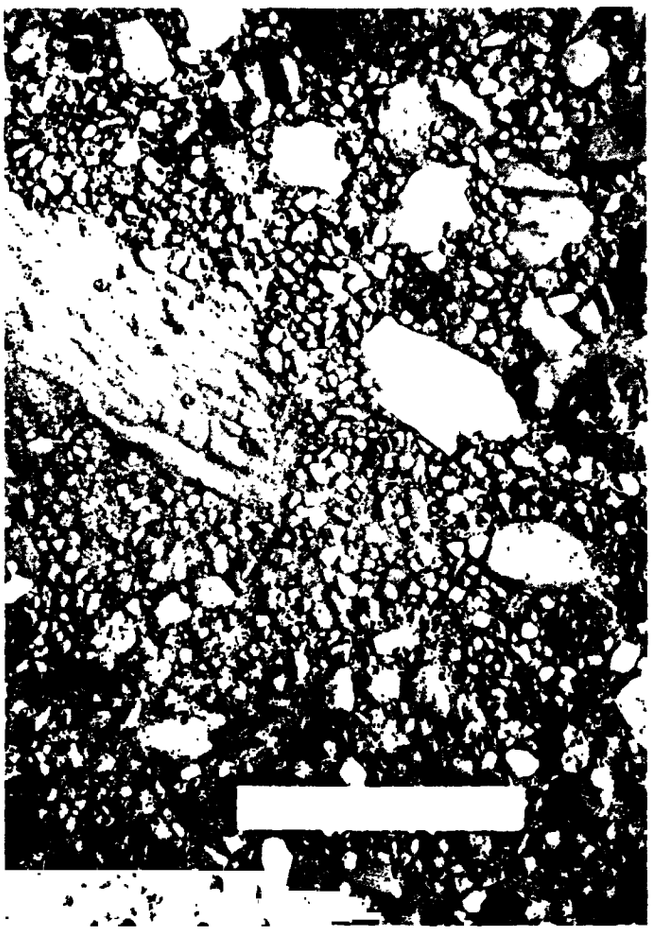


Fig. 11. Close-up of sharp, angular, and weathered rocks and gravel overlaying soil

Table 1. Antarctic soils: physical determinations

Soil No.	Soil depth	Color & Munsell notation		Textural class	*In situ* moisture, % wt	Bulk density, g/cc	Porosity, %	Unconfined strength, kg/cm^2	Temperature, °C		Relative humidity, %	
		In situ	Dry						max	min	max	min
500	Surface 2 in.	7.5 YR 6/6 pinkish grey	10 YR 6/4 light yellowish brown	Sand	1.4	1.69	36.2	<0.25 to 0.75	+2.0[b]	−5.5[b]	73.0	50.5
501	2 to 6 in.	7.5 YR 6/6 pinkish grey	10 YR 6/4 light yellowish brown	Sand	1.3	1.68	36.6	1.75 to >4.5	−4	−7.5	87.0	78.0
502	1 ft	7.5 YR 6/6 pinkish grey	10 YR 6/6 brownish yellow	Sand	1.6	1.62	38.9	2.0 to 3.75	−6	−9.0	86.5	81.0
503	1.5 ft	2.5 YR 6/2 light brownish grey	5 YR 6/4 pale olive	Sand	10.2	—[a]	—[a]	>4.5	—[a]	—[a]	—[a]	—[a]

[a]Hard, icy permafrost, temperature = −11°C.
[b]Temperature at 2-in. depth.

Table 2. Antarctic soils: physicochemical determinations

Soil No.	Soil depth	pH	Eh	Electrical conductivity	Loss on ignition	Cation exchange capacity
		Saturated paste	Saturated paste, + mv[a]	Saturated paste ECX 10^6 mho/cm at 25°C	30 min at 750°C, % wt	meq/100 gm soil
500	Surface 2 in.	8.0	403	3360	1.56	2.56
501	2 to 6 in.	7.6	416	3040	1.07	2.90
502	1 ft	7.6	439	4160	1.19	2.42
503	1.5 ft	8.3	491	1920	1.26	2.76

[a]Includes cell K = +243 mv.

Table 3. Antarctic soils: chemical determinations, % of dry weight

Soil No.	Soil depth	Total organic matter	Total carbon	Total nitrogen	Organic carbon	Organic nitrogen	Carbonate carbon	Total hydrogen	C:N total	N:H total	H:C total
500	Surface 2 in.	0.153	0.096	0.041	0.087	0.007	0.011	0.153	2.3	0.27	1.6
501	2 to 6 in.	0.233	0.163	0.033	0.135	0.012	0.008	0.142	4.9	0.23	0.9
502	1 ft	0.160	0.109	0.028	0.093	0.007	0.011	0.118	3.9	0.24	1.1
503	1.5 ft	0.308	0.185	0.018	0.179	0.007	0.017	0.134	10.3	0.13	0.7

moist to the 1.5-ft depth, where icy, hard permafrost was encountered. Bulk density decreased slightly with depth and varied inversely with porosity values. Bulk density and porosity values were comparable to those of other sandy or loamy desert soils. Soil hardness also increased with depth, exceeding 4.5 kg/cm^2 at the depth of hard, icy permafrost. With depth of profile, the soil became increasingly more difficult to dislodge.

The soil temperature decreased and relative humidity increased with depth below the surface. The soil was continually frozen below the 4-in. depth, and never reached the melting point of the liquid phase. It is doubtful that the relatively higher subsurface humidity values provided any available vapor phase for the activity of microorganisms. They would also have had to overcome the continual below freezing conditions.

Physicochemical determinations are indicated in Table 2. The pH values were typical for saline soils, which ordinarily have pH values less than 8.5. These measurements were similar to pH values obtained for other Antarctic soils (Refs. 4, 10, and 17). Eh values were also typical, which is not uncommon for oxidized desert soils when analyses are performed on processed samples in the laboratory. However, *in situ* Eh measurements were made, with values recorded between + 670 and + 780 mv (uncompensated). These latter values were extraordinarily high and have not been previously encountered in our determinations of *in situ* redox potentials in desert soils.[c] If these values are valid (they were determined at two soil pits in McKelvey Valley on two separate occasions), this environment could be limiting for some microorganisms (Ref. 18). Cation exchange capacities were quite low and were similar to those obtained for the Valley of 10,000 Smokes, Alaska; Kau Desert, Hawaii; and Eastern Sahara Desert, Egypt; as well as the Atacama Desert, Chile (SPS 37-38, Vol. IV).[6] Cation exchange capacities were lower than for those determined for Southwestern United States desert soils (Ref. 19).

Electrical conductivity and cation exchange capacity values also indicated a saline soil, although weight loss upon ignition was typical of many desert soils low in organic matter and clay which contain comparatively little other volatile materials, except "bound" water or salts. Electrical conductivity values for soil pastes, which were generally one-half to two-thirds lower for 1:5,

[c]JPL Desert Microflora Program, unreported results. 1961 to date.

Table 4. Antarctic soils: abundance of chemical elements, % of dry weight

Element	Soil number			
	500	501	502	503
O	49.74	50.74	51.0	50.9
Si	28.5	28.5	32.0	32.0
Al	6.0	5.8	4.25	4.65
Ca	5.6	5.0	4.6	4.75
Fe	4.05	4.7	3.55	3.4
Mg	2.45	2.4	2.25	2.25
Na	1.6	1.3	0.96	0.83
S	0.723	0.209	0.297	0.055
Ti	0.425	0.36	0.25	0.22
K	0.4[a]	0.4[a]	0.4[a]	0.4[a]
H	0.153	0.142	0.118	0.134
C	0.096	0.163	0.109	0.185
Mn	0.085	0.110	0.099	0.081
N	0.041	0.033	0.028	0.018
P	0.037	0.029	0.027	0.024
Cr	0.031	0.034	0.0235	0.0275
Sr	0.0155	0.0205	0.0165	0.0220
Zr	0.0120	0.0150	0.0135	0.0130
Ni	0.0103	0.0110	0.0086	0.00635
Va	0.0088	0.0093	0.00555	0.00945
Cu	0.0079	0.0079	0.0057	0.00595
Co	0.0053	0.0059	0.0057	0.00435
Ga	0.003[b]	0.003[b]	.0003[b]	0.003[b]
Ag	0.00094	0.00358	0	0
Sn	0.002[c]	0.002[c]	0	0

[a]0.4% or less.
[b]0.003% or less.
[c]0.002% or less.

soil:water extracts, would be restrictive for the growth of some plants, and would also be more favorable for the growth of halophiles.

Chemical determinations for C, N, and H are indicated in Table 3. As shown in this table, C, N, and H were relatively evenly distributed with depth of soil profile. These values compared favorably with similar analyses of typically organically poor Southwestern United States desert soils (Ref. 14). Compared with analyses of soils from the Chilean Atacama Desert, the values were also similar, except that total hydrogen was lower than for any of the 39 Atacama Desert samples. Organic carbon has not been detected in some Antarctic soils (Ref. 4), but this depends to some extent on the level of sensitivity of the method of analysis. Low hydrogen values were consistent with the mineralogy of the Antarctic samples, as well as with the low organic matter and clay content.

Table 5. Antarctic soils: "available" ions

Cation or anion	Soil number				Concentration, ppm
	500	501	502	503	
Ca^{++}	+	+	+	+	> 5
Na^{+}	+	+	+	+	> 1
Mg^{++}	–	–	–	–	< 100
K^{+}	–	–	–	–	< 10
Mn^{++}	–	–	–	–	< 10
NH_4^{+}	Tr	Tr	–	–	= 10 for Tr
$SO_4^{=}$	+	+	+	+	> 10
Cl^{-}	+	+	+	+	> 1
NO_3^{-}	+	+	+	+	> 100
$PO_4^{\equiv}$	–	–	–	–	< 10
NO_2^{-}	Tr	Tr	Tr	Tr	=0.1 for Tr

+ = presence
– = not detectable
Tr = detectable trace

C:N values, as based on total carbon and nitrogen, also compared favorably with values obtained for other desert soils with narrow ratios. The organic C:organic N values were two to three times as wide as the total C:N, and would indicate that the C and N in these samples (except for soil 503) were constituents of microbial cells or of relatively decomposed materials. With such narrow C:N values, there is probably very little or no organic natter that would not be readily utilizable or available in a more favorable solclime (soil–temperature–moisture regime). Total N:H values and H:C values showed a similarity to Chilean Atacama Desert soils with a significant amount of NO_3^{-} or NH_4^{+}[6].

The "available" or water-soluble cations and anions in the 1:5, soil:water extracts are given in Table 4. As is indicative of saline soils, the chief anions are $SO_4^{=}$ and Cl^{-}, although NO_3^{-} and a trace of NO_2^{-} are also present. Ca^{++} and Na^{+} were the chief cations. Absence of detectable Mg^{++}, K^{+}, Mn^{++}, and $PO_4^{\equiv}$ is quite significant since the availability of these ions is essential for growth and reproduction of organisms. A comparison of the concentration of these ions in Table 4 with the abundance of elements in Table 5 indicates the relative availability status of these elements.

Table 6. Antarctic soils: microbiological determinations

Soil No.	Soil depth	Incubation temperatures, °C	Microorganisms per gram of soil									
			Aerobes	Anaerobes	Microaerophiles[b] dilutions			Fungi	Algae[b] dilutions		Actinomycetes	Sulfate reducers
					10	10^2	10^3		10	10^2		
500	Surface 2 in.	Room temperature[a]	30	25	+	−	−	1.5	+−	−	0	0
		+ 4	8	10	+	−	−		−[c]	−[c]	0	0
		+55	0									
501	2 to 6 in.	Room temperature[a]	13	10	+	+	−	1	−	−	0	0
		+ 4	27	30	+	+	+[d]		−[c]	−[c]	0	0
		+55	0									
502	1 in.	Room temperature[a]	14	10	+	+−	−	1	−	−	0	0
		+ 4	18	35	+	−	−		−[c]	−[c]	0	0
		+55	0									
503	1.5 ft	Room temperature[a]	43	<10	+	+−	−	0	−	−	0	0
		+ 4	10	<10	+	−	−		−[c]	−[c]	0	0
		+55	2									
Culture medium			Trypticase soy agar	Trypticase soy agar (Pyrogallic acid + NaOH)	Fluid thioglycollate			Rose Bengal agar and Sabouraud dextrose agar	Thornton's medium less organics		Bacto actinomycete agar	Van Delden's sulfate reduction agar

[a]Room temperature incubations usually varied between +15 to +23°C.
[b]Checked microscopically for growth (+ = growth; − = no growth).
[c]Incubation temperatures usually varied between −2 to +15°C.
[d]One discrete colony present.
All incubations conducted in the National Science Foundation Biology Lab., McMurdo Sound Station, Antarctica, between Dec. 19, 1966 and Jan. 31, 1967.

There was a slight or significant decrease in abundance of most elements with depth of soil. This decrease in elements was counterbalanced by an increase in Si. Although some elements—S, Cr, Ni, and Co—were of higher concentration than in some desert soils, the low abundance of K was notable, when compared with some Hawaiian desert soils.[6]

Abundance of common groups of microflora found in these soils is shown in Table 6. In all four soil samples, there were aerobic, anaerobic, and microaerophilic bacteria and/or yeasts. The abundance of these groups of microflora was quite low, much lower than for typical U.S. desert soils, and comparable to the lowest abundances encountered in some of the soils from the Valley of 10,000 Smokes, Alaska; Kau Desert, Hawaii; and Atacama Desert, Chile. However, in some of the saline Atacama Desert samples, the actinomycete (streptomycete) abundance in fluid thioglycollate (verified microscopically) approached values of 10^8/g soil! The abundances of algae, fungi, and sulfate-reducing microorganisms were among the lowest values encountered in desert soils, and were also comparable to the same levels, or absence, of these groups of microflora in soil samples from the Valley of 10,000 Smokes, Alaska; Kau Desert, Hawaii; Eastern Sahara Desert, Egypt; and the Atacama Desert, Chile.[6] A filamentous, nonnitrogen-fixing blue-green alga, *Schizothrix calcicola* (Fig. 12), grew in only one triplicate 10-g sample of surface soil 500. A mold, *Penicillium* sp. (Fig. 13), was also found, except in sample 503. Several other molds were observed on the culture plates, but they were probably laboratory contaminants.

Most of the cultures grew slowly; they contained nonpigmented rather than pigmented colonies, and spreading rather than discrete colonies in the surface soils (Fig. 14). On agar plates, the colonies usually grew out from soil particles distributed on the surface of the agar (Fig. 15). Microorganisms did not grow well when the soil was diluted, whether in agar or in tubes of culture media. If growth did occur in the 10^2 dilution of 1 g of soil, it was all below the surface of the culture medium, indicating that growth took place under microaerophilic rather than aerobic conditions.

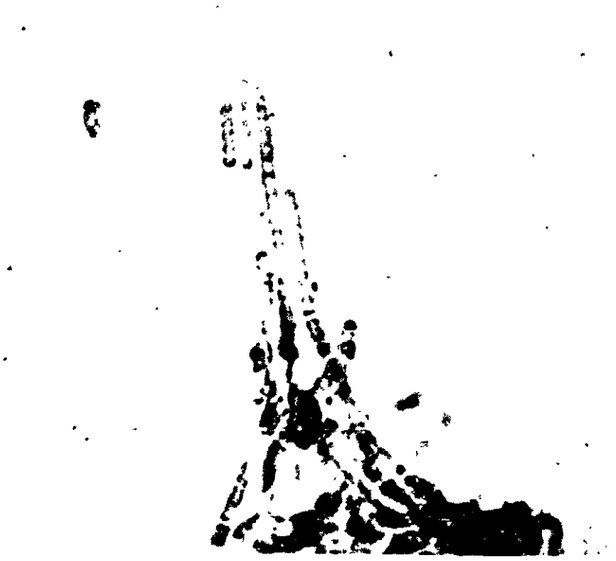
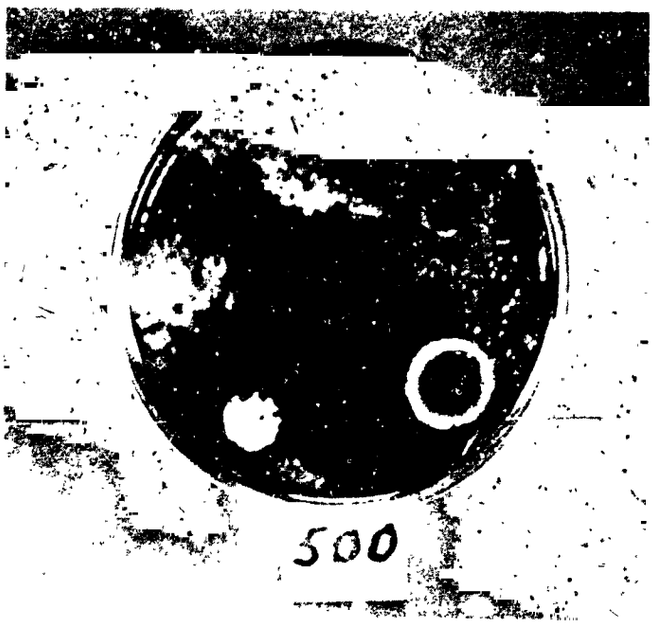
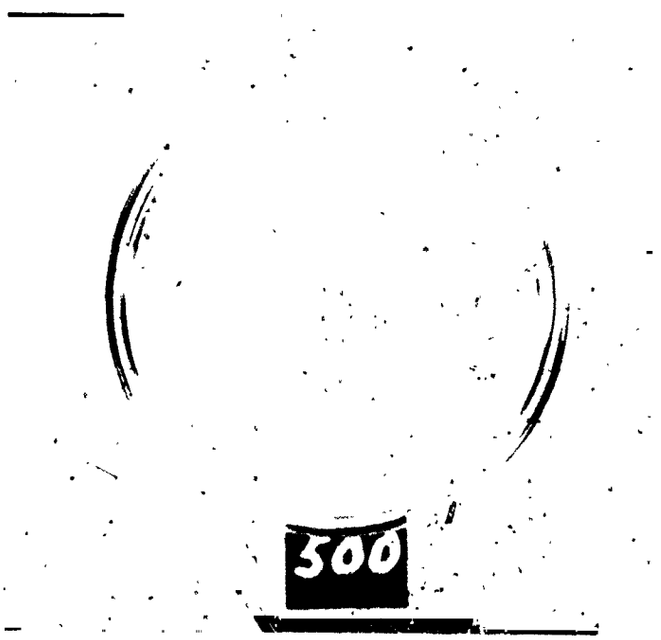


Fig. 12. Photomicrograph (× 1250) of blue-green alga, *Schizothrix calcicola*, cultured from 10 g of surface soil sample 500



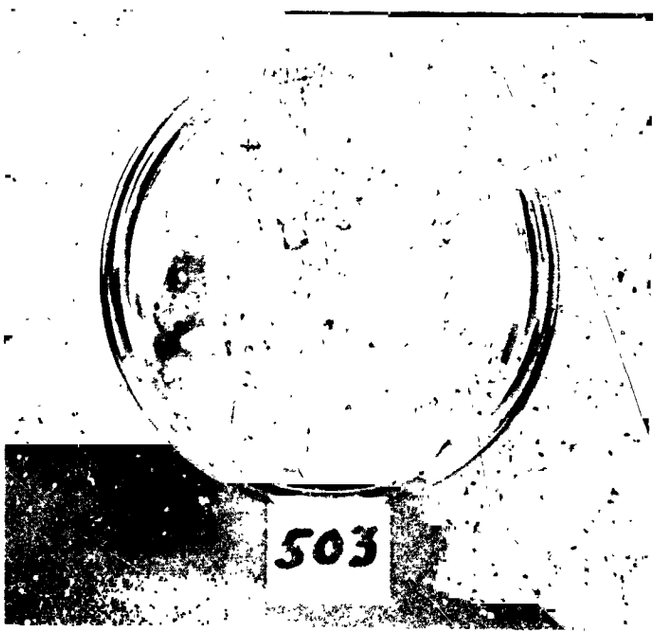
Photograph by C L. Hall.

Fig. 14. Spreading pigmented and nonpigmented bacterial colonies (and one mold) cultured from 1 g of soil 500 sprinkled on surface of trypticase soil agar



Photograph by C. L. Hall, Virginia Polytechnic Institute, Blacksburg, at NSF Biology Laboratory, McMurdo Sound, Antarctica.

Fig. 13. Two colonies of *Penicillium* sp. cultured from 1 g of soil 500 sprinkled on surface of Rose Bengal agar



Photograph by C. L. Hall.

Fig. 15. Glistening bacterial colonies growing out from 1 g of soil particles sprinkled on surface of trypticase soy agar. Agar plate cultured at +4°C under anaerobic conditions

Although there were mesophiles which grew at room temperatures (Fig. 14), as well as microorganisms capable of growing at 4°C, the difference in abundance was not appreciable, as shown in Table 6. A thermophile capable of growing at +55°C (Fig. 16) was actually found in sample 503, from a depth of 1.5 ft. Since this was the only thermophile encountered, it may possibly be a contaminant that entered the sample during collection procedures. Some of the microorganisms may be heat-sensitive, and for subsurface soils 502 and 503, more bacteria were obtained by streak plates than by pour plates with warm agar (approximately 40°C).[7]

As shown in Table 6, there are as many, if not more, microorganisms below the surface than in the surface sample 500. This abundance of microorganisms was more apparent with fluid thioglycollate medium than with other media and was also evident when comparing streak plates with pour plates for these four soils.[7]

Gram stains of microorganisms cultured from the soil samples showed gram-positive, -negative, and -variable bacterial rods (Figs. 17 and 18) and gram-positive and gram-negative cocci (Fig. 19), especially gram-positive diplococci. Yeasts also made up a significant proportion of the microflora. Soil diptheroids and actinomycetes, which have been found in many other desert soils examined for this program, were not found in the four soil samples from McKelvey Valley.

[7] Streak plates prepared by R. E. Benoit, Virginia Polytechnic Institute, Blacksburg, Virginia.

Photograph by C. L. Hall.

Fig. 16. White bacterial colonies cultured at +55°C and growing out from 1 g of soil particles sprinkled on surface of trypticase soil agar

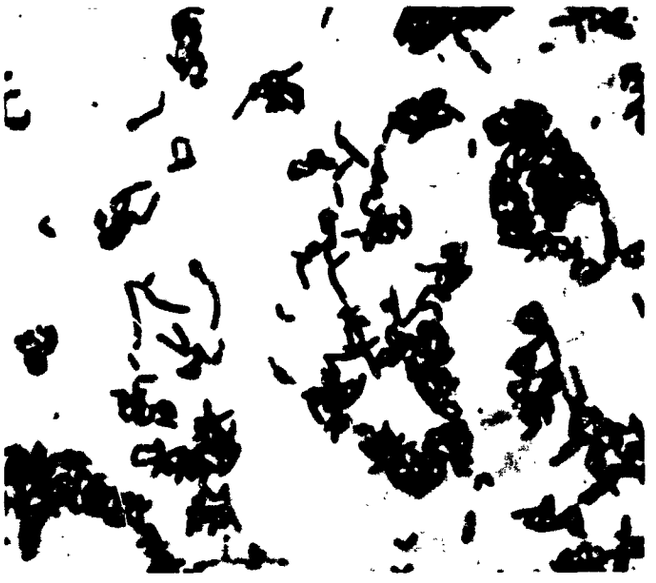


Fig. 17. Photomicrograph (×1250) of gram-variable bacterial rods cultured from soil 503. Isolant taken from agar plate illustrated in Fig. 15

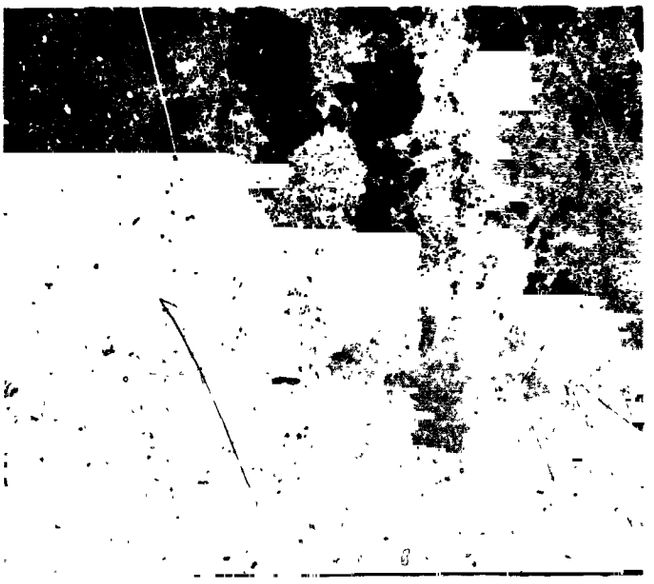


Fig. 18. Photomicrograph (×1250) of gram-positive and gram-negative bacterial rods cultured in fluid thioglycollate medium from soil 503

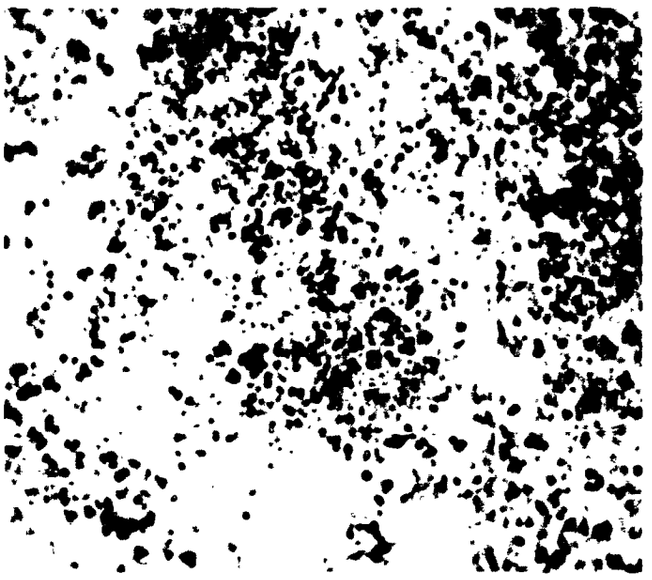


Fig. 19. Photomicrograph (× 1250) of gram-positive and gram-negative bacterial cocci cultured from soil 500 at room temperature. Isolant taken from agar plate illustrated in Fig. 14

4. Concluding Remarks

Four samples from one soil site in McKelvey Valley, Antarctica were studied and their properties compared with values obtained for other desert soils. For most soil properties, there was generally not much variation with depth to hard, icy permafrost. Soil temperatures decreased with depth as the relative humidity and moisture values increased. Water availability, because of below freezing temperatures, was a definite limiting factor for activity of microorganisms.

All of the soil samples showed properties of a saline soil, with significant amounts of detectable Ca^{++}, Na^{+}, $SO_4^{=}$, NO_3^{-}, and Cl^{-}. There was a noticeable lack of water-soluble K^{+}, Mg^{++}, Mn^{++}, and $PO_4^{\equiv}$. Determinations for pH, electrical conductivity, and *in situ* Eh indicated that the soil environment would be restrictive to some microorganisms, but favorable for salt-tolerant organisms or halophiles. The cation exchange capacity was quite low.

Although the soil site and general area in McKelvey Valley showed no evidence of human contamination prior to this study, the presence of a skua and one piece of desiccated seal skin indicated that contamination with some organics could have occurred. The winds that blew across the valley usually came from the direction of the sea and brought in some air contaminants, but these microorganisms appeared to be similar to other microorganisms (bacteria and fungi) cultured from the surface soil.

Abundance of common groups of microflora in these soils was very low or nil, and much lower than for typical United States desert soils. Some of the highest values were obtained with fluid thioglycollate. The abundances of algae, fungi, and sulfate-reducing microorganisms were among the lowest values encountered in any other desert soils previously analyzed. The actinomycetes, which were the most abundant populations in the extremely arid Chilean Atacama Desert, were not found in the samples of Antarctic soil, but the soil microflora contained a significant proportion of yeasts.

Mesophiles, as well as microorganisms with psychrophilic capabilities, and aerobes, anaerobes, and microaerophiles were present but not abundant, as determined by the culture methods used for this study. These microorganisms usually grew slowly, and were nonpigmented rather than colored colonies. More spreaders were found in the 6-in. surface of soil than in the samples procured from lower depths. There were as many, if not more, microorganisms in the subsurface samples than in the surface sample. This same phenomenon has also been observed for soils from the Atacama Desert and the Sahara Desert.[6] However, in the samples from Antarctica, it was observed that heat sensitivity could be an important factor in obtaining viable microorganisms.[7]

Additional Antarctic soils from other dry valleys will be analyzed and studied. The abundances of microflora were determined for this study utilizing routine media, and may not have revealed the presence of specialized physiological groups, such as halophiles. These and other microflora will be sought later. Soil extracts of Antarctic materials will also be used in culture media. It is quite obvious that the ecology of Antarctic soil microflora is complex, and that the presence or abundance of soil microflora is limited by factors that are unfavorable for the survival, growth, and reproduction of organisms. The Antarctic dry valleys can provide valuable information prior to the search for extraterrestrial life in other harsh environments. *In situ* investigations, as well as laboratory studies, should not be neglected for the Antarctic continent.

B. Triaxial Jet Hydrogen Flame Ionization Detector, *E. M. Bollin*

During the investigation of pyrolysis of life-related compounds, it became necessary to design a hydrogen

ionization detector that could operate under conditions not generally encountered in gas chromatography. The flame detector was used to monitor the products from a differential thermal analysis (DTA)–effluent gas analysis (EGA) thermal head assembly. Several commercial flame detectors were evaluated. However, the DTA instrumentation and the manner in which it was used required the development of a specialized detector for convenience and flexibility.

The triaxial jet detector (Fig. 20) developed during this study proved to be very flexible and stable. The detector stabilized within 10 min after ignition, and was used unshielded, without a detector oven, and exposed to a strong fluctuating draft from air-conditioning. Normal gas flows were as follows: carrier, 30 to 90 cc/min; hydrogen, 60 cc/min; and air, 300 to 600 cc/min.

The detector was assembled from a Gelman 1-in.-diameter aluminum closed filter holder, stainless-steel tubing, and Swagelock fittings. The cap of the filter holder was thinned to provide clearance for the collector electrode. This was the only machining necessary. When the larger cap of the Gelman stainless-steel pressure filter funnel is used, no machining other than drilling and tapping is necessary. Modification of the Swagelock fittings noted in Fig. 20 may be achieved by drilling. The Microdot bulkhead connector will accommodate slight differences in collector loop wire size by modification of the spring ferrule tension. The fittings were assembled with Teflon front ferrules during initial adjustment and alignment.

Aside from the obvious ease and simplicity of construction of this detector, there are certain design concepts not immediately obvious that contribute greatly to the function of this device as a stable detector capable of operating well under conditions normally not acceptable, nor required, in standard gas chromatography work.

Since the inception of the device, the need for a laminar flame structure has been recognized by most workers in the field. The rather long vertical tube dimensions, which are required by the Swagelock fittings to assemble the triaxial jet, contribute to a great degree in ensuring that laminar flame conditions prevail. The tube length for each component is in the correct order for its respective sensitivity to nonlaminar conditions: the hydrogen, longest; the sample, intermediate; and air, shortest.

The design of the air jet contributes especially to the insensitivity of the device to fluctuating ambient conditions. The air flow may be increased to nearly blast conditions without creating flame turbulence or an increase in background noise due to nonlaminar conditions. The flame is insulated from the environment by this rapidly moving annular sheet of collimated air. A sufficient amount of air diffuses toward the flame to support combustion. A short distance beyond the primary reaction zone the air flow pattern becomes divergent. This permits a considerable variation in the hydrogen flow and in the position of the collector ring. For any specific hydrogen flow and collector position, the air flow may be adjusted to maintain the collector just below incandescence. Below this point, fluctuations in flow rates have little effect upon background current.

The separate jet for carrier gas and sample allows a considerable variation in other parameters that normally affect a flame detector. Because of the large area of this jet orifice, rather large variations in carrier flow have very little effect upon the flame size and shape. In normal practice, carrier flow is restricted to the small diameter of the hydrogen jet and combined with the hydrogen flow. Therefore, it is competitive with the hydrogen in determining the configuration of the flame, and the sensitivity of a change in flow can be rather large. Although some doubt was experienced concerning the possible loss of sample by outward diffusion into the air stream, no such effect could be found. The diffusion of the air through the sample to the hydrogen results in molecular diffusion driven by a steep concentration gradient in such a manner as to contain the sample rather completely. The divergent cone of the air jet above the region of primary reaction also further contains the sample within the reaction zone. Another mechanism of sample entrapment is the gas acceleration (which may exceed 1000 g) due to the extreme temperature gradient at the primary reaction front of the flame. This serves very effectively to pull the sample into the reaction zone. When operating the detector just below incandescence of the collector, a small shift in base line is noticeable when the carrier gas flow is stopped completely. However, operation of the detector is not otherwise disturbed.

The triaxial configuration allows further freedom in detector design. Since a much smaller total volume of gas is handled by the hydrogen jet, the constraints of carrier gas irregularities do not have to be compensated by low pressure drop at the jet. Thus, the jet may be made much smaller than normal. This allows a higher velocity of hydrogen within the plane of the orifice while still maintaining a laminar flame, and moves the transport or preheat region slightly farther from the face of the jet. This results in a flame reaction front that tends to be less

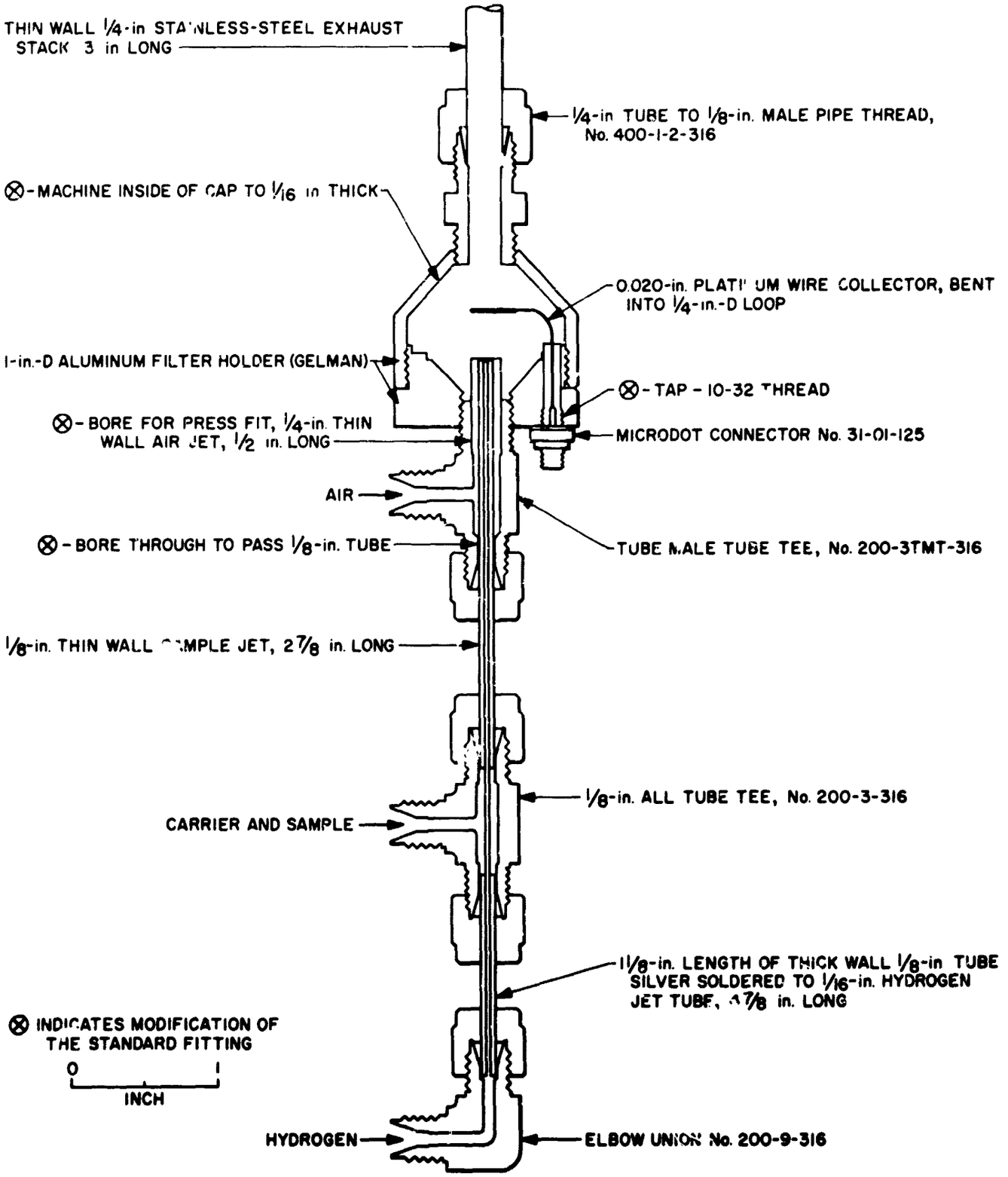

THIN WALL 1/4-in STAINLESS-STEEL EXHAUST STACK 3 in LONG
1/4-in TUBE TO 1/8-in. MALE PIPE THREAD, No. 400-1-2-316
⊗ - MACHINE INSIDE OF CAP TO 1/16 in THICK
0.020-in. PLATINUM WIRE COLLECTOR, BENT INTO 1/4-in.-D LOOP
1-in.-D ALUMINUM FILTER HOLDER (GELMAN)
⊗ - TAP - 10-32 THREAD
⊗ - BORE FOR PRESS FIT, 1/4-in. THIN WALL AIR JET, 1/2 in. LONG
MICRODOT CONNECTOR No. 31-01-125
AIR
⊗ - BORE THROUGH TO PASS 1/8-in. TUBE
TUBE MALE TUBE TEE, No. 200-3TMT-316
1/8-in. THIN WALL SAMPLE JET, 2 7/8 in. LONG
1/8-in. ALL TUBE TEE, No. 200-3-316
CARRIER AND SAMPLE
1 1/8-in. LENGTH OF THICK WALL 1/8-in TUBE SILVER SOLDERED TO 1/16-in. HYDROGEN JET TUBE, 2 7/8 in. LONG
⊗ INDICATES MODIFICATION OF THE STANDARD FITTING
0
1
INCH
HYDROGEN
ELBOW UNION No. 200-9-316

Fig. 20. Triaxial jet hydrogen flame ionization detector

efficient in heating the jet to incandescence, which is an important source of noise. With the smaller orifice, thicker walled tubing with a higher thermal mass, which contributes to the conduction of heat from the jet, may be used.

An additional feature of the triaxial configuration, and one that has not yet been examined, is the rather long path length over which the sample is exposed to ultraviolet radiation before entering the flame reaction zone. The large area of the sample jet and the complete optical filling of its opening by the primary reaction zone of flame provide an approximate 3-in. length of tubing that is intensely illuminated by ultraviolet radiation. This could possibly excite many molecular species to a high level before entering the reaction zone. How or to what extent this mechanism may contribute to the performance of the detector is not known.

References

1. Weyant, W. S., "The Antarctic Climate," in *Antarctic Soils and Soil Forming Processes*, pp. 47–59, J. C. F. Tedrow, Editor, American Geophysical Union of the National Academy of Sciences, National Research Council, Washington, D.C., 1966.
2. Rubin, M. J., "Antarctic Climatology," in *Biogeography and Ecology in Antarctica*, pp. 72–96, J. Van Mieghem, P. Van Oye, and J. Schell, Editors, Dr. W. Junk Publishers, The Hague, 1965.
3. Rudolph, E. C., "Terrestrial Vegetation in Antarctica: Past and Present Studies," in *Antarctic Soils and Soil Forming Processes*, pp. 109–124, J. C. F. Tedrow, Editor, American Geophysical Union of the National Academy of Sciences, National Research Council, Washington, D.C., 1966.
4. Tedrow, J. C. F., and Ugolini, F. C., "Antarctic Soils," in *Antarctic Soils and Soil Forming Processes*, pp. 161–177, J. C. F. Tedrow, Editor, American Geophysical Union of the National Academy of Sciences, National Research Council, Washington, D.C., 1966.
5. Llano, G. A., "The Flora of Antarctica," in *Antarctica*, pp. 331–350, T. Hatherton, Editor, Frederick A. Praeger, Inc., New York, 1965.
6. Llano, G. A., "The Terrestrial Life of the Antarctic," *Scientific American*, Vol. 207, pp. 212–230, 1962.
7. Dodge, C. W., "Lichens," in *Biogeography and Ecology in Antarctica*, pp. 127–193, J. Van Mieghem, P. Van Oye, and J. Schell, Editors, Dr. W. Junk Publishers, The Hague, 1965.
8. Cameron, R. E., and Blank, G. B., *Desert Algae: Soil Crusts and Diaphanous Substrata as Algal Habitats*, Technical Report 32-971, Jet Propulsion Laboratory, Pasadena, Calif., July 15, 1966.
9. Sieberth, J. N., "Microbiology of Antarctica," in *Biogeography and Ecology in Antarctica*, pp. 267–295, J. Van Mieghem, P. Van Oye, and J. Schell, Editors, Dr. W. Junk Publishers, The Hague, 1965.
10. Boyd, W. L., Staley, J. T., and Boyd, J. W., "Ecology of Soil Microorganisms of Antarctica," in *Antarctic Soils and Soil Forming Processes*, pp. 125–159, J. C. F. Tedrow, Editor, American Geophysical Union of the National Academy of Sciences, National Research Council, Washington, D.C., 1966.

References (contd)

11. Cameron, R. E., Blank, G. B., and Gensel, D. R., *Sampling and Handling of Desert Soils*, Technical Report 32-908, Jet Propulsion Laboratory, Pasadena, Calif., April 15, 1966.

12. Jackson, J L., *Soil Chemical Analysis*, Prentice-Hall, Inc., Englewood Cliffs, N.J., 1958 (498 pp).

13. Chapman, H. D., and Pratt, P. F., *Methods of Analysis for Soils, Plants, and Water*, University of California, Berkeley, Calif., 1961 (309 pp).

14. Cameron, R. E., and Blank, G. B., *Soil Organic Matter*, Technical Report 32-443, Jet Propulsion Laboratory, Pasadena, Calif., May 23, 1963.

15. Allen, O.N., *Experiments in Soil Bacteriology*, Third Edition, Revised, Burgess Publishing Co., Minneapolis, Minn., 1957 (117 pp).

16. Bull, C., McKelvey, B. C., and Webb, P. N., "Quaternary Glaciations in Southern Victoria Land, Antarctica," *Journal of Glaciology*, Vol. 4, pp. 63–78, 1962.

17. Claridge, G. G. C., "The Clay Mineralogy and Chemistry of Some Soils from the Ross Dependency, Antarctica," *New Zealand Journal of Geology and Geophysics*, Third Special Antarctic Issue, Vol. 8, pp. 186–220, 1965.

18. Baas Becking, L. G. M., Kaplan, I. R., and Moore, D., "Limits of the Natural Environment in Terms of pH and Oxidation-Reduction Potentials," *Journal of Geology*, Vol. 68, pp. 243–284, 1960.

19. Cameron, R. E., "Soil Sampling Parameters for Extraterrestrial Life Detection," *Journal of the Arizona Academy of Science*, Vol. 4, pp. 3–27, 1966.